Including additional weather terms in CWV – Jason Blackmore

An Approach

This document details an approach that can be used to incorporate solar radiance into the existing CWV calculation. The approach could also be used for other weather variables.

Firstly, the CWV calculation was replicated in Excel for the history 01/01/2016 to 27/02/2018 and compared to CWV actual from another source to confirm the calculation and underlying data was correct. The results were verified[1].

Next, a solar term was calculated and added to the CWV calculation. A Demand/Solar+CWV optimisation was carried out keeping the current CWV parameters the same, while the Solar Weight was allowed to flex to better fit demand as measured by R2.

Table 1: LDZ EM CWV parameters shows the original CWV parameter weights for EM together with the Optimised parameter weights and the additional Solar Weight term – here 0.681. On the right Chart 1: R2 visualisation shows the R2 of the CWV and SCWV models. For many LDZs SCWV improved the fit shown in the Table 2: summary of SCWV results.

The SCWV – (Solar plus Composite Weather Variable) calculation

Firstly, starting with the CWV calculation, this is a function of the following three components:

- Wind Speed – Computed by taking an average of three hourly wind speed figures over the gas day
- Effective Temperature (ET) – Half of today's Actual Temperature (AT) + Half of yesterday's ET
- Seasonal Normal Effective Temperature – Calculated using 18 years of data from 1996/97 to 2013/14
- $CW = I_1 ET_D + (1 - I_1) SNET_D - I_2 \max \ (0, WS - W_0) \max \ (0, T_0 - AT)$
- $CWV = \begin{cases} V_1 + q(V_2 - V_1), & CW \geq V_2 \\ V_1 + q(CW - V_1), & V_1 < CW < V_2 \\ CW, & V_0 \leq CW \leq V_1' \\ CW + I_3(CW - V_0), & CW < V_0 \end{cases}$

Next, a solar radiance (SR) measurement is calculated as follows:

- Actual Solar (AS) – Computed by the sum of hourly solar radiance observations over the gas day
- Seasonal Normal Solar (SNS) – Sum of the hourly seasonal normal solar observations from the CCM data sets
- $SR = \log AS_D - \log SNS_D$

The SCWV calculation includes an additional Solar Term:

- $Solar\ Term = S_1 SR$
- $SCWV = CWV + Solar\ Term$

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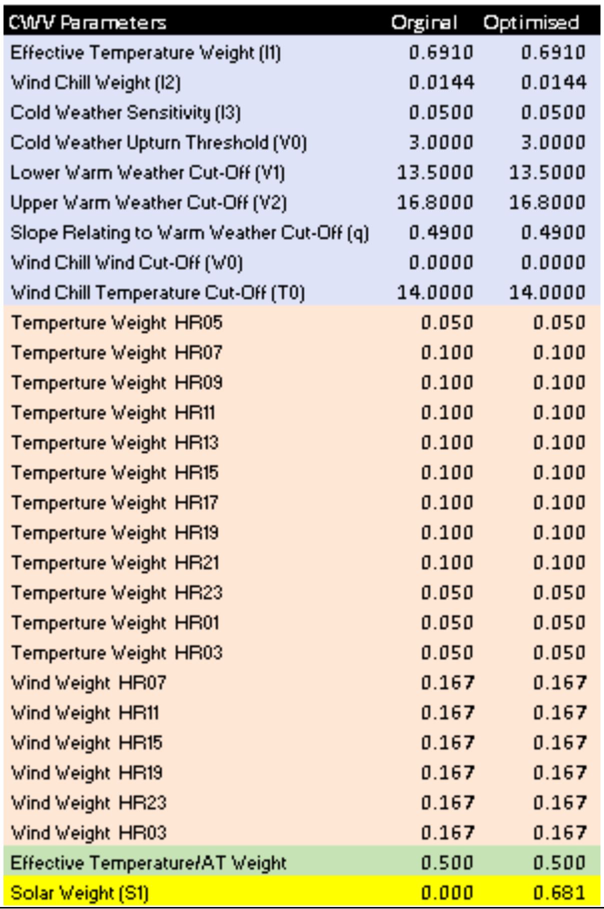
[1] *One area of difference was the additional decimal point precision used in the Excel calculation improved the results slightly approx. 0.03% each month improvement*

Table 1: LDZ EM CWV parameters – used in the optimisation. Note only the Solar weight was allowed to change.



CWV Parameters	Orginal	Optimised
Effective Temperature Weight (I1)	0.6910	0.6910
Wind Chill Weight (I2)	0.0144	0.0144
Cold Weather Sensitivity (I3)	0.0500	0.0500
Cold Weather Upturn Threshold (V0)	3.0000	3.0000
Lower Warm Weather Cut-Off (V1)	13.5000	13.5000
Upper Warm Weather Cut-Off (V2)	16.8000	16.8000
Slope Relating to Warm Weather Cut-Off (q)	0.4900	0.4900
Wind Chill Wind Cut-Off (W0)	0.0000	0.0000
Wind Chill Temperature Cut-Off (T0)	14.0000	14.0000
Temperture Weight HR05	0.050	0.050
Temperture Weight HR07	0.100	0.100
Temperture Weight HR09	0.100	0.100
Temperture Weight HR11	0.100	0.100
Temperture Weight HR13	0.100	0.100
Temperture Weight HR15	0.100	0.100
Temperture Weight HR17	0.100	0.100
Temperture Weight HR19	0.100	0.100
Temperture Weight HR21	0.100	0.100
Temperture Weight HR23	0.050	0.050
Temperture Weight HR01	0.050	0.050
Temperture Weight HR03	0.050	0.050
Wind Weight HR07	0.167	0.167
Wind Weight HR11	0.167	0.167
Wind Weight HR15	0.167	0.167
Wind Weight HR19	0.167	0.167
Wind Weight HR23	0.167	0.167
Wind Weight HR03	0.167	0.167
Effective Temperature/AT Weight	0.500	0.500
Solar Weight (S1)	0.000	0.681

Chart 1: R2 visualisation - A visualisation of the fit of the CWV and SCWV models. A desired result was that observations differing from the regression line would move closer to the regression line.

For LDZ EM the R2 improved from 0.9788 to 0.9798. In MAPE terms this improved from 4.70% to 4.47%.

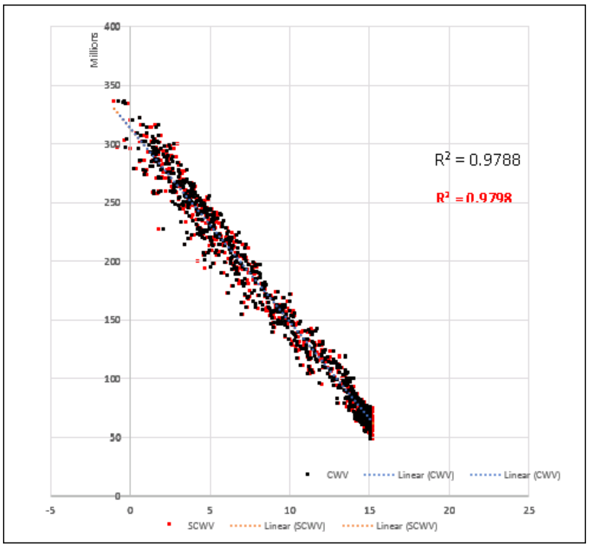


Table 2: Summary of SCWV results

LDZ	CWV - MAPE	SCWV - MAPE	Solar Weight
EA	5.15%	5.12%	0.404
EM	4.70%	4.47%	0.681
NE	5.67%	5.51%	0.374
NO	5.67%	5.53%	0.388
NT	4.18%	4.15%	0.353
NW	4.54%	4.46%	0.656
SC	4.49%	4.41%	0.173
SE	5.43%	5.38%	0.254
SO	5.56%	5.50%	0.237
SW	5.18%	4.84%	0.304
WM	6.42%	6.37%	0.281
WN	4.66%	4.66%	0
WS	12.72%	12.74%	0.293

Measuring Solar

For our design we wanted SCWV to be higher than CWV on bright days to provide lower demand on bright days. We also wanted a result where if there was no solar effect then SCWV = CWV. Our many gas systems and processes use CWV and thus any improvement needed be incremental to CWV, not a different form. We were also happy for the SCWV to flex outside of the summer cut-off, SCWV could be higher than max CWV. We are happy with this, as it introduced some general optimisation.

One problem is that solar is a highly seasonal measurement, much higher in the summer, which is being modelled against a highly variable gas measurement, much higher in the winter. A monthly approach to the analysis would produce greater over fitting of the results and a complicated optimisation. Therefore the solar measurement used was a daily sum of hourly solar observation minus its seasonal normal equivalent (which was taken from CCM datasets) and then a log of the daily solar and normal series was used, log(solar) – log(solar seasonal normal) as shown in Figure 2: Solar Radiance Transformations[2].

Figure 1 Daily Totals of Solar Radiance:

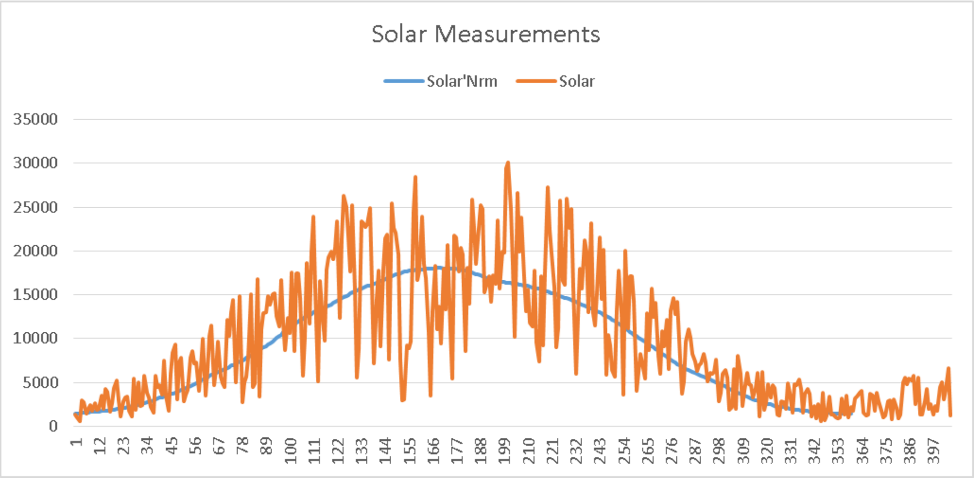
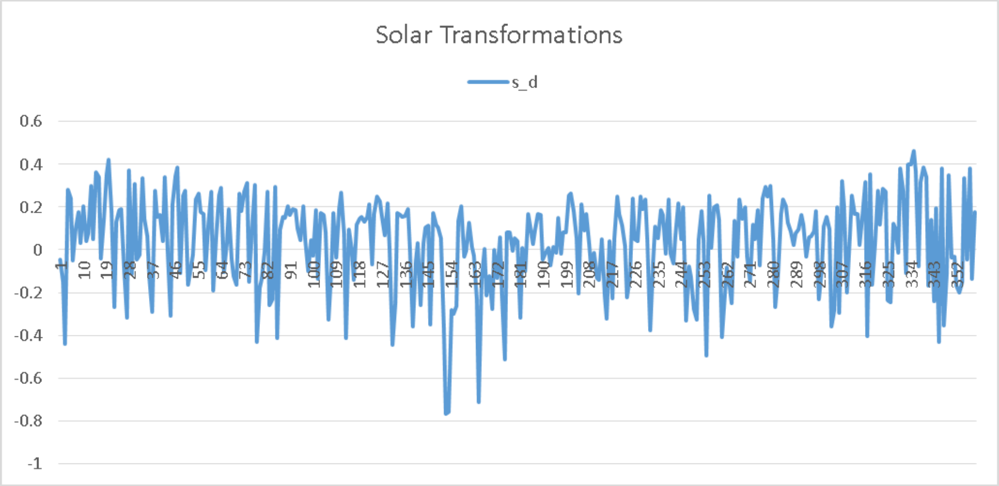


Figure 2: Solar Radiance after Log Transformations



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[2] In the future a Box-Cox transformation could be applied instead – a type of variance equalising transformation.

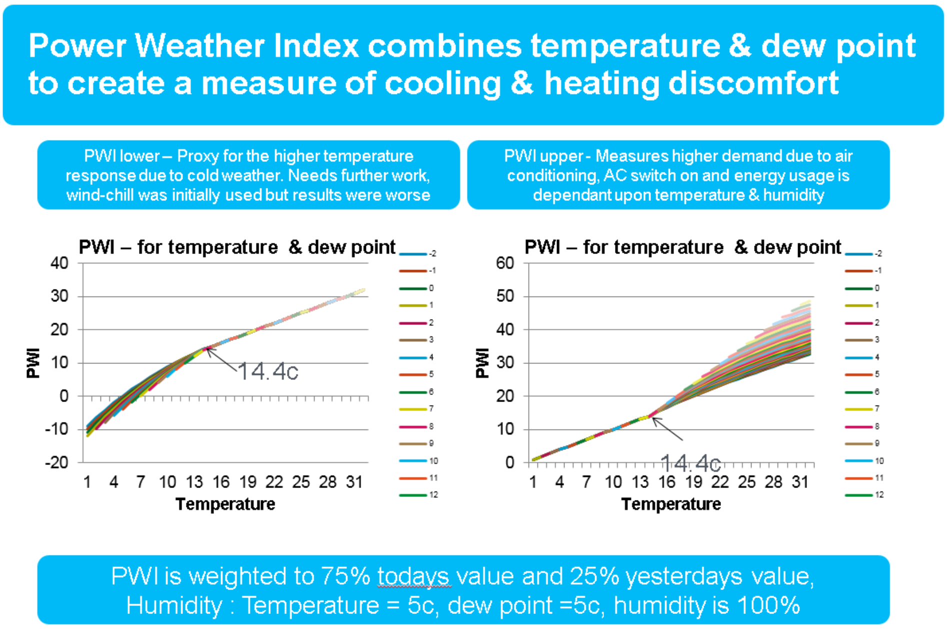
The transformation chosen attempts to produce a solar measurement which has a constant mean and variance - visually it achieves this reasonably well in figure 2. [3]

Other incremental improvements to CWV - options

Summer Simmer Index – a variable that combines *temperature* and *humidity* is extensibility used in parts of North America in modelling TSO demands.

I adapted this concept to form a Winter Chill Index[4] (and therefore assert my rights to be identified as the creator of this variable). For electricity data this had shown better results than the traditional use of wind-chill in analysis. It’s an example of different weather modelling variables that could be used in combination with CWV.

Given the system constraints, it may be difficult to radically create new variables. However there is an option for these modelling variables to be calculated by the weather provider and input (as a temperature definition) into the existing calculation.



Power Weather Index combines temperature & dew point to create a measure of cooling & heating discomfort

PWI lower – Proxy for the higher temperature response due to cold weather. Needs further work, wind-chill was initially used but results were worse

PWI upper - Measures higher demand due to air conditioning, AC switch on and energy usage is dependant upon temperature & humidity

PWI is weighted to 75% todays value and 25% yesterdays value,
Humidity : Temperature = 5c, dew point =5c, humidity is 100%

Other observations on CWV

Below the components of CWV are shown against demand to highlight which parts of the CWV calculation are more or less important.

For example, the AT definition improves slightly over a simple average of hourly temperatures.

The SNET term and seasonal cut-offs are the most important part of the CWV calculation.

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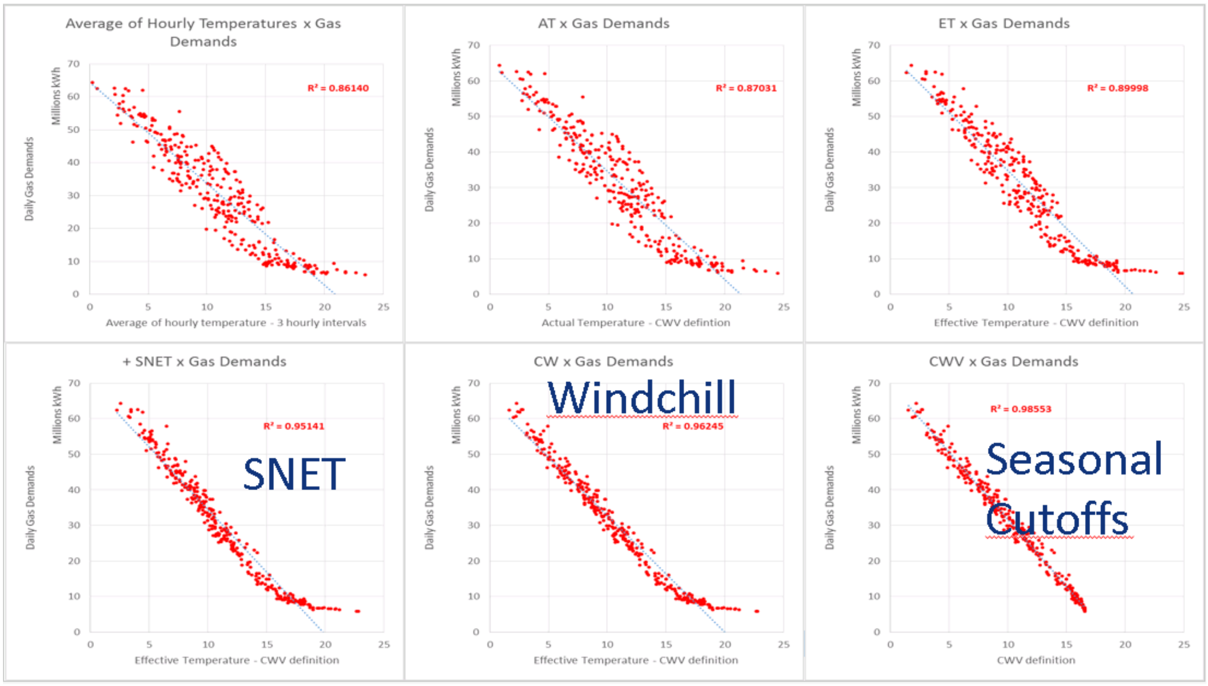
[3] The transformation does produce a result where a summer solar impact produces the same CWV effect (and therefore same demand effect) as a winter solar impact (a linear response) – which may not be true.

[4] The concept of a winter chill index was adapted from the SSI concept, to provide a lower measure of temperature when humidity is higher.



In summary, CWV is the right approach to model gas demands and any improvement should be incremental and build upon the approach so far. There is some scope from including additional weather terms into the calculation and this SCWV approach is one method that highlights how this can be done with the constraints of systems.

Although SCWV improves our own analysis, I have the following comments on it:

- The likely effect from lower heating demands from high levels of solar radiance on bright winter days is much smaller than the behavioural effect from customers remaining indoors due to the rain.
- Therefore Solar is in part of proxy measurement for customer behaviour and rainfall.
- Rainfall events are actually (in modelling terms, rare events) and the customer behavioural effect is calendar related (Weekend and wet days – impact customer behaviour much greater than weekday). Which in part is why the improvements in R2 appear small, while the MAPE improvements are higher.